Tracking Medical Students and Graduates from Hometown to Practice using Geographic Information Systems, 2011-2017

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Abstract

Background: Indiana University School of Medicine (IUSM) through its statewide system provides medical education and clinical experiences across Indiana for more than 1450 medical students in nine regions, including Indianapolis and eight regional medical campuses (RMCs). The majority of medical students begin their education distributed among the RMCs, and some students continue clinical experiences at the RMCs for their third and fourth years.
Methods: We used a Geographic Information System (GIS) to visualize and document the contribution of our RMCs in Indiana to the physician workforce pipeline. Using data from the 2011-2017 graduating classes, we created a geospatial database that linked key information from student records and public domain sources (e.g., hometown, campus assignment, PGY1 specialty, and practice) with their corresponding locational information. ArcGIS 10.5 GIS software was used to produce a series of maps to visualize patterns in student outcomes among the RMCs over time.
Results: By using GIS to track medical trainees from hometown to practice, we can provide accurate visualization of extensive geographic data. The maps revealed similarities and differences among the RMCs not fully appreciated until visually mapped, including the specialty choice of students from different campuses and the proportion of graduates practicing in medically underserved areas of the state.
Conclusions: GIS maps and their analyses can identify strengths and distinctions among the RMCs while providing accurate descriptions of the role of geography in the professional development journey of the physician workforce. This ongoing project is a major step toward integrating GIS as a familiar tool in academic administration and health workforce research to assist future decision-making by the school leadership.

Introduction

According to the Liaison Committee for Medical Education (LCME), there are currently 166 LCME-accredited medical schools in the United States and Canada.[1] About a third (55) of these schools operate regional medical campuses (RMCs) in geographically separate locations from the main medical campus.[2] Although RMCs must comply with the same LCME standards as the school's main medical campus to ensure high-quality comparable education, the RMCs often have a unique focus or mission that differs from their parent campus (e.g., rural medicine).[3] Cheifetz et al.[4] have proposed a classification system for RMCs based primarily on student class years on campus. With this system, RMCs can be classified into one of four models: *basic science*, *clinical, longitudinal,* or *combined*, depending on the particular mix of basic science and clinical instruction at a given campus.

The Indiana University School of Medicine (IUSM) employs a large geographically distributed system of medical education, with over 1450 students enrolled across eight RMCs and the main medical campus in Indianapolis. Approximately two-thirds of each entering class is distributed among the eight RMCs associated with university campuses at Bloomington, Evansville, Fort Wayne, Northwest (located in Gary), Muncie, South Bend, Terre Haute, and West Lafayette. The remainder of the class matriculates at Indianapolis. Using the

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nomenclature of Cheifetz et al.[4], the RMCs of IUSM would be classified under the *combined* model. IUSM RMC students complete their basic science years one and two onsite. They may also complete their clinical years three and four at the RMC, or they may opt to return to Indianapolis to complete their clinical years. In addition, IUSM provides postgraduate training for nearly 1200 residents and 90 fellows per year through its 141 residency and fellowship programs. Knowing exactly where our future physicians are coming from and where they eventually settle into practice can provide critical information for medical school administrators and policy makers who must strategically align IUSM's educational mission with the physician workforce needs of the region, thereby facilitating more equitable distribution of the physician workforce in Indiana. However, tracking medical trainees in such a large and complex system presents a formidable administrative challenge.

To address this challenge, we employed a Geographic Information System (GIS) to track our trainees through the medical education 'pipeline' from their hometown origin to their professional practice location. The power of GIS to store, analyze, and display data linked to geographic locations provides a visually-striking and easily understood way to convey complex information to administrators and policy makers. Although GIS is frequently used to investigate spatial relationships of health and disease, such as in disease mapping and access to care studies[5], there are relatively few examples of GIS being used for administrative purposes in medical education. For instance, some investigators have used GIS to assess the spatial distribution, or 'footprint', of family medicine residency graduates in relation to patient populations in areas of need.[6,7] We are not aware of any published studies using GIS to track a large cohort of students from a single medical school across the continuum of medical education—from their hometown and college, entry into medical school, through residency and fellowship, and into professional practice.

The purpose of this study was two-fold. The first was to compare the career paths of students at RMCs and students at the Indianapolis campus in terms of their hometown origin, specialty choice, and practice location, particularly relative to Health Professional Shortage Areas (HPSAs) or Medically Underserved Areas (MUAs).[8] The second was to provide a practical example of how GIS can be used to inform decision-making and visually demonstrate the merits and unique attributes of RMCs.

The Campuses and Communities of Indiana's Statewide System

The eight cities hosting the RMCs represent the largest population centers outside of Indianapolis (Table 1). Each RMC is located on the campus of a local university, which provides the academic infrastructure for the faculty. All of the RMCs develop strong partnerships with their local medical communities to support students' clinical education.

By virtue of their locations, the RMCs produce graduates that are well-attuned to the local health care needs of the community. Some graduates will return to the campus region to practice primary care medicine which helps alleviate local shortages of health care providers. This is because all of the IUSM campuses, except the Fort Wayne RMC, are located in either a primary care HPSA or a MUA. The Health Resources and Services Administration (HRSA) defines HPSAs as geographic areas and populations with health care provider shortages in primary care, dental care, or mental health; MUAs are defined as geographic areas with inadequate access to primary care services.[8] Although several eligibility criteria are used in defining HPSAs and MUAs, the population to provider ratio is especially important in both designations. There are currently 160 primary care HPSAs and 45 MUAs in Indiana, which collectively encompass 36% of the state's population.[8]

Due to the strict LCME accreditation standards mandating comparable educational experiences across multiple campuses, IUSM closely monitors the curriculum delivery, student support services, and all other campus operations

to assure that the education of students is as similar as possible across all instructional sites.

Table 1 - Demographic Characteristics of Cities with IUSM Campuses

City	Population	Age			Race			Income and Employment		Education
		0-17	18-64	65+	White	Black	Other	Median Household Income	Jobless Rate	College-Educated Adults
Bloomington	83,093	12%	80%	8%	82%	4%	14%	$31,254	8%	57%
Evansville	120,156	22%	63%	15%	82%	12%	6%	$36,330	7%	20%
Fort Wayne	260,954	26%	61%	13%	74%	15%	11%	$44,449	8%	27%
Gary	77,858	26%	58%	16%	14%	82%	5%	$28,895	17%	13%
Indianapolis	856,196	25%	64%	11%	62%	28%	10%	$43,230	9%	29%
Muncie	69,583	17%	69%	14%	84%	10%	7%	$31,373	11%	23%
South Bend	101,037	28%	60%	12%	62%	27%	11%	$35,758	11%	24%
Terre Haute	61,021	20%	67%	13%	83%	9%	8%	$33,378	10%	22%
West Lafayette	44,543	10%	83%	7%	71%	3%	26%	$28,793	5%	69%

Data from: www.statsamerica.org/town

Methods

Using data from the 2011-2017 graduating classes of IUSM, we compiled a geospatial database that linked student data obtained from official school records with locational information about graduates acquired from publically-accessible sources. The Office of Medical Student Education provided us with information concerning each graduate's hometown, IUSM campus assignment, and PGY1 Match specialty. Google searches of university and hospital websites were conducted to determine each graduate's professional practice location as of the summer of 2017. In this manner, a longitudinal record of each graduate's journey through the medical education pipeline was created to facilitate individual tracking.

After the completion of the geospatial database, ArcGIS 10.5 software (ESRI, Redlands, CA) was used to produce a series of maps to illustrate the career progression and location of these graduates over time. Data was aggregated across the study period to provide a more robust sample size and dampen the effects of year-to-year variation in graduating classes.

For the purposes of this study, three maps have been selected that visually highlight similarities and differences in the graduating classes associated with each of the nine IUSM campuses. These three maps show the composition of each campuses' graduating class relative to the county of their hometown, PGY1 Match specialty, and current practice location relative to HPSAs or MUAs.

Results

Table 2 summarizes the entire cohort of IUSM graduates by their hometown, PGY1 Match specialty, and practice location relative to HPSAs or MUAs.

Table 2 – Characteristics of Indiana University School of Medicine Graduates (2011-2017)

Hometown [a] (2012-2017)				Specialty [b] (2011-2017)				Practice [c] (2011-2013)			
Within campus region		Outside campus region		Primary Care		Non-Primary Care		Within HPSA or MUA		Outside HPSA or MUA	
#	%	#	%	#	%	#	%	#	%	#	%
709	37%	1,189	63%	812	38%	1,329	62%	306	40%	458	60%

[a] Hometown data unavailable for 2011 graduates
[b] Primary care is defined as general internal medicine, family medicine, and pediatrics (including internal medicine-pediatrics)
[c] Graduates of 2014-2017 are not yet in practice

IUSM divides the state into nine non-overlapping campus regions (shown using bold black lines in Figure 1). Each campus region consists of the county containing the IUSM campus and a surrounding cluster of contiguous counties. These nine campus regions represent each campus's recognized sphere of influence with regard to fundraising, community support, and clinical affiliations. As a group, the majority of graduates (63%) had hometowns in counties located outside the region of the IUSM campus they attended. Most of the IUSM graduates entered a specialty care field (62%), and after their post-graduate training, the majority of IUSM graduates (60%) settled into practice locations outside of HPSAs or MUAs in Indiana or elsewhere. In contrast to these aggregate statistics, the maps revealed some interesting variations among the RMCs and Indianapolis campus.

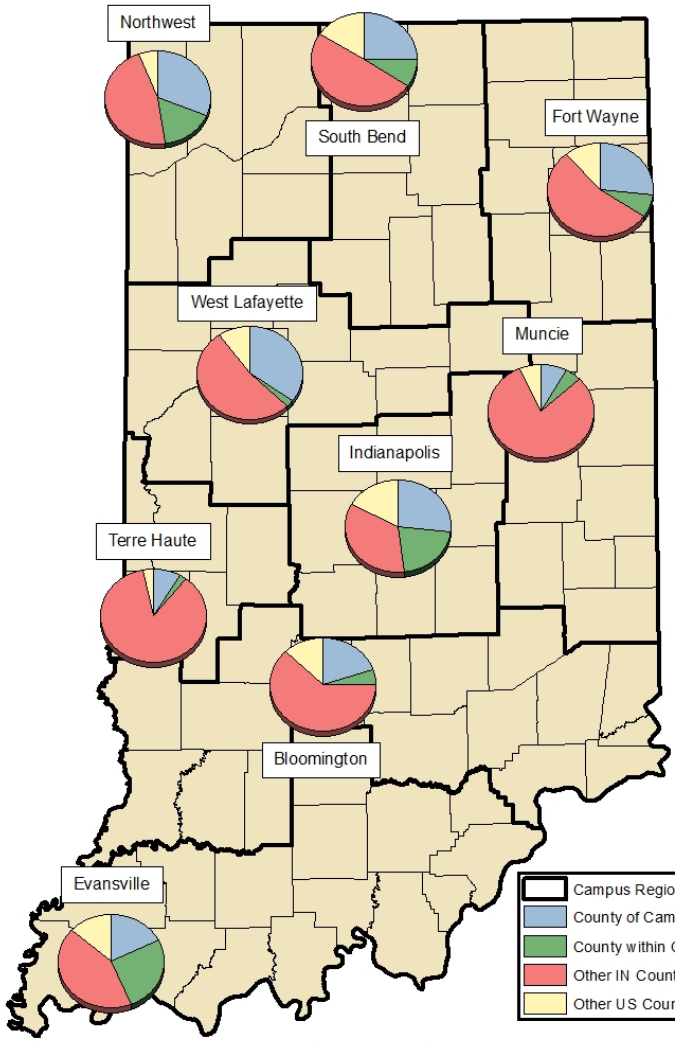

Figure 1: Hometown Counties of IUSM Graduates by Campus, 2012-2017

As shown in Figure 1, nearly half of the graduates from the Northwest RMC (48%) and Indianapolis campus (48%) originated from the corresponding campus regions (blue and green wedges), whereas only 11% of the graduates from the Terre Haute RMC had hometowns in its region. The remaining RMCs had intermediate values between these two extremes.

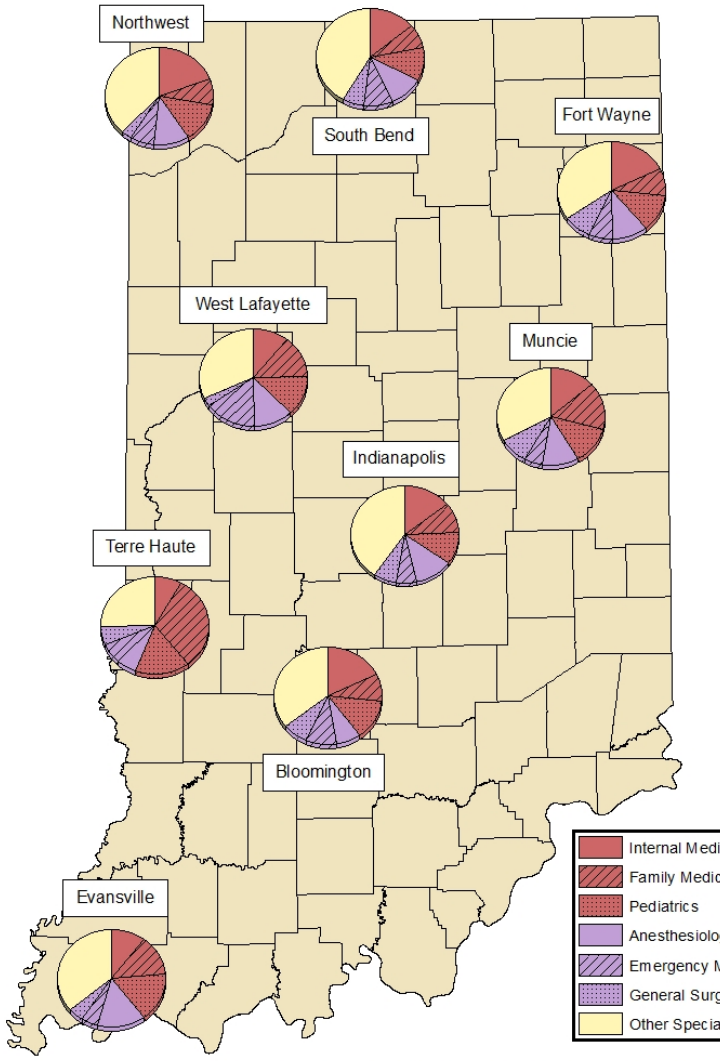

Figure 2: Top Residency Specialties of IUSM Graduates by Campus, 2011-2017

Figure 2 shows that the proportion of graduates entering the primary care fields of general internal medicine, family medicine, and pediatrics (including internal medicine-pediatrics) was similar among all of the IUSM campuses (ranging from 32%-41%), with the notable exception of the Terre Haute RMC, which had over one-half (56%) of its graduates match into primary care fields. Also, the Terre Haute RMC had a greater proportion of its graduates entering family medicine than any other IUSM campus.

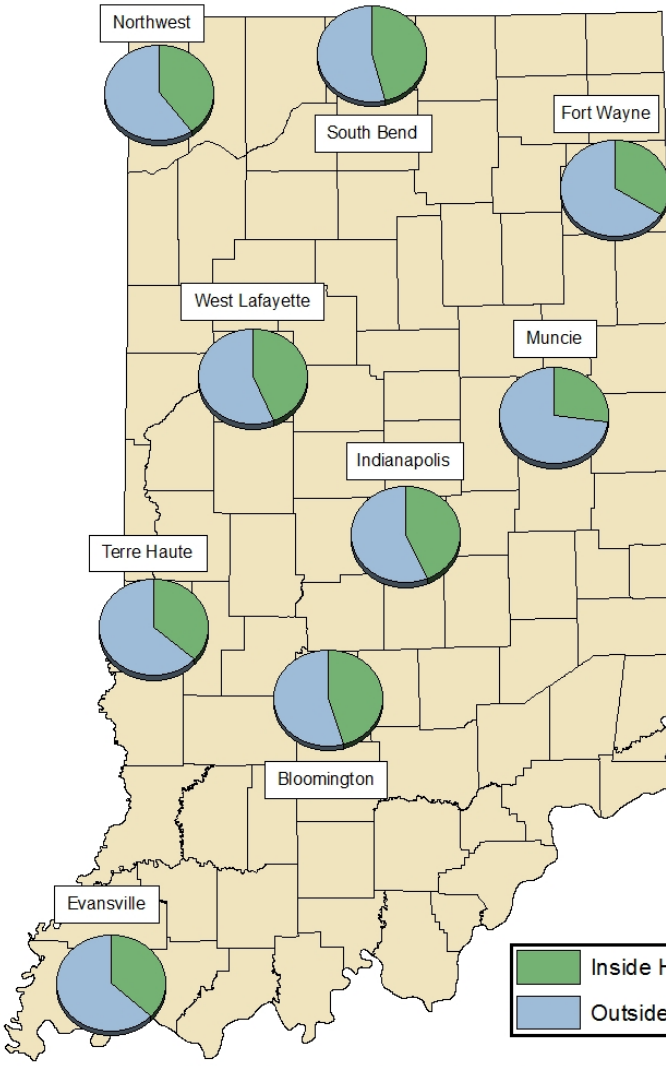

Figure 3: IUSM Graduates Practicing in HPSAs and/or MUAs by Campus, 2011

As is evident in Fig. 3, the graduates from the RMCs are no more likely to practice in HPSAs or MUAs compared to graduates from the Indianapolis campus. The South Bend and Bloomington RMCs produced the greatest proportion (45%) of graduates practicing in HPSAs or MUAs, and the Muncie RMC produced the smallest (27%).

Discussion

Using GIS, we have traced the career paths of IUSM students at the RMCs and Indianapolis campus from their place of origin, through their medical training, and into practice. The resultant maps revealed patterns that are easily discerned and interpreted with minimal effort, which is perhaps the greatest advantage of GIS. Although the same data could be presented in tabular format for each campus, the underlying patterns would not be as readily apparent nor as compelling as when presented in maps. When sharing class data with the school leadership, we have found that maps such as these can communicate key similarities and differences among the RMCs and the Indianapolis campus effectively, and can even help dispel some long-held misconceptions about the RMCs.

To properly interpret our maps, it is necessary to understand how newly admitted students are assigned to a campus. The assignment of students to an RMC or the Indianapolis campus is not random, but based on a combination of student preference and the availability of space. When students are notified of their acceptance into medical school, they are asked to rank order their preferred campus assignment. The campus assignment process occurs after acceptance into medical school and has no bearing on the admission decision (e.g., a student cannot enhance his or her chances of admission by expressing a desire to attend an RMC). A computerized lottery system is used to optimally match each student's rank list to the available campus capacity at the time of assignment. Certain categories of accepted students automatically receive their first choice of campus assignment (e.g., early decision applicants), whereas others are not given the option of campus preference and are assigned strictly on the basis of available space (e.g., late admits taken from the alternate list). As might be expected, not all IUSM campuses are equally popular with students. A few campuses, especially Indianapolis, receive more first-choice requests for assignment than available space permits, but other campuses must fill their classes with students who would have preferred another campus assignment.

When the study cohort was entering medical school during the 2007-2013 timeframe, IUSM was incrementally expanding the class size from 294 in 2007 to 344 in 2013. Over one-half of each incoming class was assigned to the RMCs. For example, the entering class of 2013 was distributed as follows: Indianapolis (138), Bloomington (36),

Fort Wayne (32), Northwest (26), Muncie (24), South Bend (24), Terre Haute (24), Evansville (20), and West Lafayette (20). IUSM currently admits 364 students per year and the majority (62%) are assigned to the RMCs.

The map of hometown origins (Fig. 1) reflects both the vagaries of the school's campus assignment process as well as the unique attributes of each IUSM campus that may serve to attract an incoming student. As a state-supported medical school, IUSM favors Indiana applicants over non-residents, which comprise only 15%-20% of the entering class overall. It is therefore expected that the vast majority of students assigned to IUSM campuses are Indiana residents. What is noteworthy, however, is that some RMCs are able to fill a sizable portion of their entering class with students from the surrounding campus region, but other RMCs fill primarily with students from more distant regions of Indiana. In the case of the Terre Haute RMC, the relatively small subset of students from that campus region is explicable because this particular RMC offers a unique curricular track for students interested in rural medicine, which will naturally attract students from across the state. The observed variation in the proportion of RMC students who are from the corresponding campus region is probably attributable to several factors, including the number of students accepted into medical school from that particular region and how those students rank the local RMC during the campus assignment process.

After graduating from medical school during the 2011-2017 timeframe, most of the study cohort entered post-graduate training in specialty fields, especially anesthesiology, emergency medicine, and general surgery. A smaller percentage of the cohort matched into primary care. What is particularly revealing about the map of top specialties (Fig. 2) is that most of the RMCs appear to produce about the same proportion of specialists as the Indianapolis campus, which contradicts a common misconception about the RMCs—that they are designed chiefly to produce primary care physicians, particularly family practitioners. The Terre Haute RMC does produce proportionally more primary care physicians than any other IUSM campus, but that is largely due to its special Rural Medical Education Program, which emphasizes primary care. In contrast, the other RMCs tend to mirror the Indianapolis campus in terms of specialist production, suggesting that students attending the RMCs and Indianapolis campus have similar career aspirations.

When IUSM's statewide system of medical education was established in the early 1970s, it was generally assumed that students who were exposed to the training environments of the RMCs would be predisposed to eventually return to those regions to practice, and that they would be more inclined to practice primary care medicine. By analyzing a large dataset of IUSM graduates from the classes of 1988-1997, researchers found that students who attended the RMCs were statistically more likely to practice primary care medicine in local communities compared to students who attended the Indianapolis campus.[9,10] However, in the ensuing 20-30 years since these graduates completed residency and settled into practice, the RMCs have evolved considerably and are no longer limited to pre-clinical education since they now offer third and fourth year clerkships as well. Perhaps as the training environments of the RMCs and Indianapolis campus have become more similar over time, the specialty preferences of their students have followed suit.

Another somewhat surprising observation is the relatively low percentage of RMC graduates practicing in HPSAs or MUAs, which might be assumed to be higher given the history of the statewide system of medical education. After all, one of the rationales for establishing the RMCs in the first place was to improve the supply of primary care providers to rural communities and other areas of need. Nevertheless, the map of practice locations (Fig. 3) clearly shows that the RMC graduates are no more or less inclined to practice in underserved communities than are the graduates from the Indianapolis campus, which further underscores their similar career aspirations.

Few published studies have taken advantage of GIS to track medical trainees for

research or administrative purposes, and those that have used GIS were focused on graduates of family medicine residency programs. For example, Reese et al.[6] combined information from the American Medical Association Physician Masterfile and the graduate registries for two family medicine residency programs in North Dakota and Louisiana that closed between 2000 and 2006 to determine the practice locations for 209 of the program graduates. The resultant maps revealed the local impact of the program closures on physician access in rural areas and HPSAs. In a similar study, Hixon et al.[7] mapped the practice locations for 86 University of Hawai'i Family Medicine and Community Health graduates from 1993 to 2010 to determine the percentage working in HPSAs. Our study may be the first application of GIS for the large-scale tracking of medical students across the spectrum of their training and into practice.

Limitations

As in any large dataset collated from multiple sources, our geospatial database had the inevitable missing or inaccurate data elements. We were unable to obtain the hometown information for the class of 2011, though all other data elements for that class were present. Determining the current practice locations of graduates was sometimes challenging because we relied on the accuracy of publically-accessible sources on the internet, such as hospital and clinic websites, which are not always updated in a timely manner. In addition, name changes due to marriage or other circumstances occasionally made it difficult to verify a graduate's practice location. Nevertheless, we were able to confirm the practice locations for 79% of the study cohort now in practice.

Conclusions

By using GIS to trace the career paths of IUSM students at the RMCs and Indianapolis campus over time, we have revealed some interesting aspects of the RMCs that were not fully appreciated until visualized in the form of maps. The most striking observation apparent on even casual inspection is how similar the career outcomes of the students at the RMCs versus the Indianapolis campus were with regard to specialty selection and practice location. This suggests that the training environments of the IUSM campuses are sufficiently alike to engender similar career paths for the students. We believe that GIS offers a powerful tool to track medical students across the continuum of medical education, and that the administrators and policy makers in particular can benefit from using GIS maps to inform their decision-making.

Future Studies

Although beyond the scope of this descriptive study to properly answer, our findings did raise some interesting questions about the RMCs that may warrant further study, for example:

- Why are some RMC's more popular than others in attracting newly admitted students and what can be done to enhance these students' opinions of the less popular RMCs?
- Do students who come from outside of Indiana have career aspirations different from those of Indiana students?
- Do students who were early decision admits have career aspirations different from those who were late admits?
- Is the specialty choice and practice location of graduates who spend their entire four years at a single RMC different from those who transferred to Indianapolis after two years?
- Why are some RMCs more successful than others in producing graduates who choose to practice in HPASs or MUAs?

At present, we can only speculate about the causal factors that produced our observations. More in-depth studies using both quantitative and qualitative methods will be necessary to obtain definitive answers to these questions.

References

1. Liaison Committee for Medical Education. Medical School Directory.

http://lcme.org/directory/. Accessed January 7, 2018.

2. Association of American Medical Colleges. Group on Regional Medical Campuses. Official Medical Regional Campuses May 2013. https://www.aamc.org/members/grmc/. Accessed January 7, 2018.

3. Rabinowitz HK, Diamond JJ, Markham FW, Wortman JR. Medical school programs to increase the rural physician supply: A systematic review and projected impact of widespread replication. *Academic Medicine* 2008; 83(3):235–243.

4. Cheifetz CE, McOwen KS, Gagne P, Wong JL. Regional medical campuses: A new classification system. *Academic Medicine* 2014; 89(8):1140-1143.

5. Lyseen AK, Nøhr C, Sørensen EM, Gudes O, Geraghty EM, Shaw NT, Bivona-Tellez C. A review and framework for categorizing current research and development in health related Geographic Information Systems (GIS) studies. *Yearbook of Medical Informatics* 2014; 9:110-124.

6. Reese VF, McCann JL, Bazemore AW, Phillips Jr RL. Residency footprints: Assessing the impact of training programs on the local physician workforce and communities. *Family Medicine* 2008; 40(5):339-344.

7. Hixon AL, Buenconsejo-Lun LE, Racsa CP. GIS residency footprinting: Analyzing the impact of family medicine graduate medical education in Hawai'i. *Hawai'i Journal of Medicine & Public Health* 2012; 71(4):31-39.

8. Health Resources and Services Administration Data Warehouse. Find Shortage Areas by Address.https://datawarehouse.hrsa.gov/tools/analyzers/geo/ShortageArea.aspx. Accessed February 1, 2018.

9. Brokaw JJ, Mandzuk CA, Wade ME, Deal DW, Johnson MT, White GW, Wilson JS, Zollinger TW. The influence of regional basic science campuses on medical students' choice of specialty and practice location: A historical cohort study. *BMC Medical Education 2009;* 9:29. doi:10.1186/1472-6920-9-29.

Wade ME, Brokaw JJ, Zollinger TW, Wilson JS, Springer JR, Deal DW, White GW, Barclay JC, Holloway AM. Influence of hometown on family physicians' choice to practice in rural settings. *Family Medicine* 2007; 39(4):248-254.